Proposal

on

Energy-Efficient 3D Wireless Sensor Networks

Under the Guidance of:
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FET, MUST

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Course Work Subjects

- Research Methodology (ET 901)
- Wireless Sensor Networks (EC 570)
- Foreign Language (CL 811)

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Above mentioned is the list of subjects that was finalized in my SRC. In 2013-2014, I have passed all the subjects.

Introduction to Wireless Sensor Networks

A Wireless Sensor Network (WSN) [1] consists of large number of sensor nodes deployed over a geographical area. Each sensor node is a low-power device that performs the task of sensing, collecting and transmitting data to the central collection point called sink or base station. The architecture of the WSN can reasonably be divided into the node architecture and network architecture. A WSN is equipped with one or more sensors, a radio transceiver for wireless communication, a small micro-controller for data processing and data signaling, and an energy source, usually a battery, to provide power to the sensors, the transceiver and the microcontroller.

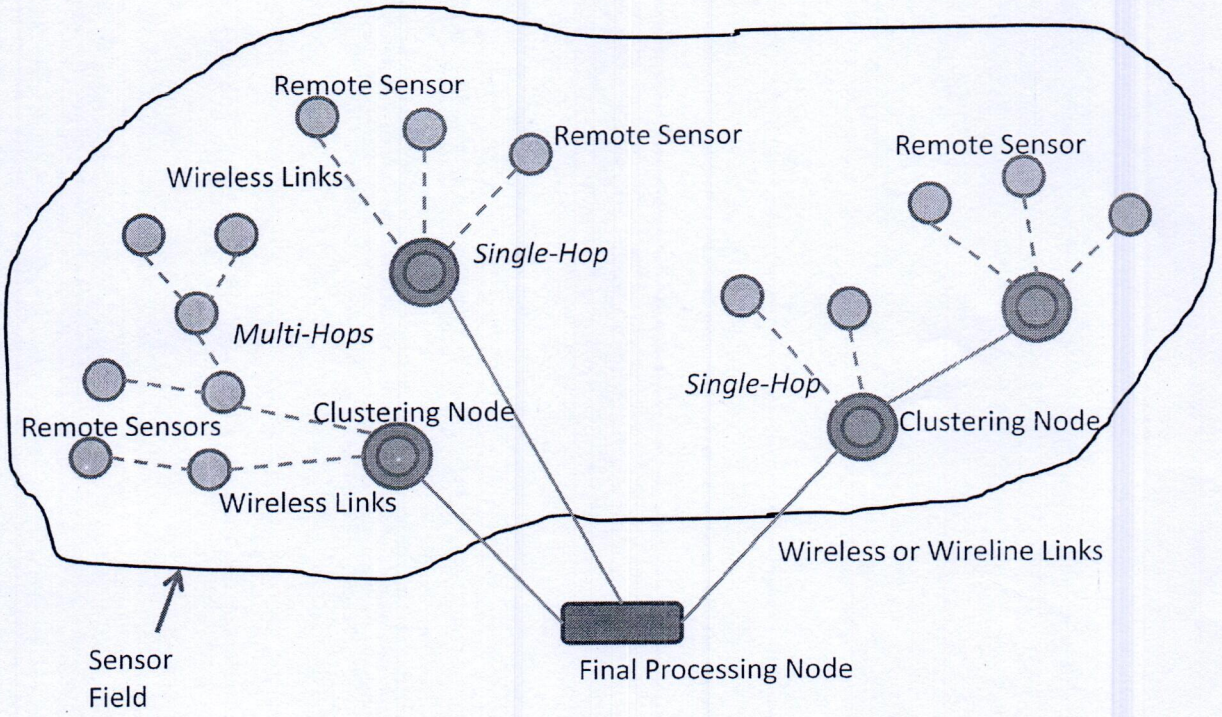

Fig 1: A Wireless Sensor Network

Typical parameters [2] to be measured by sensors include:

- *Physical Measurement*— two-axis magnetometers; light and ultraviolet intensity (photo resistor); radiation levels, radio, and microwave; humidity, temperature (thermistor), atmospheric pressure, fog, and dust; sound and acoustics; two-axis accelerometers, shock wave, seismic, physical pressure, and motion; video and image (visible or infrared); and location (GPS) and locomotion measurements

- *Chemical and Biological Measurement*— the presence or concentration of a substance or agent at specified concentration levels
- *Event Measurement*— determination of the occurrence of human-made or natural events, including cyber-level events; tracking of internal and external events

Applications of Wireless Sensor Networks

In recent years, use of WSNs has increased for a range of real-life applications. In *military operations* [3], sensor nodes are used to provide a secure, small, lightweight, cost effective and high bandwidth communication system along with resistance to electronic warfare threats. These sensors are used to measure various physical phenomena as well as to detect presence of some object or person in military areas. WSNs are used widely in the areas like *biomedical applications* [4] for monitoring patient environment as well as biological systems. In *industries* [5], WSNs are used for automation, control and real-time monitoring. By monitoring physical parameters of machinery, it is possible to prevent failures. WSNs are also used for *environmental monitoring* by detecting fire, liquid/gas leakage, radiation check etc. Some other applications of WSNs are *real-time tracking* [6], *habitat monitoring* [7], *smart home automation* [8] and other commercial tasks. Properties like ease of deployment, ability to self-organize and unattended performance of WSNs make them suitable for the areas where human presence is unsafe or impossible.

Need for Energy-Efficient Design:

Energy consumption is one of the main obstacles in WSNs, when a long network lifetime is needed. Seeing the expenditure of energy of a sensor node, communication subsystem consumes 100 times more power [1] than sensing and processing of data. Unlike in standard wireless networks, wireless sensor nodes are often deployed in unattended environments, making it difficult to change their batteries. Furthermore, recharging sensor batteries by energy scavenging is complicated and volatile. These severe constraints have a direct impact on the lifetime of a sensor node. So, in WSNs, energy is a limited source and various techniques must be employed to prolong network lifetime. One possible technique of reducing energy consumption at a sensor node is to use *low-power electronics*. The integration of low-power chips in the design of sensor nodes is a necessary step towards achieving high levels of power efficiency. However, energy

gains resulting from energy-efficient chip design can easily be wasted if the processing and communication capabilities of the sensor node are not operated efficiently. Achieving this goal requires the design of *energy aware communication protocols* at various layers of wireless communication protocol stack.

Energy efficiency can be achieved at both node and network levels. At the node level, radio management, modulation, computation, packet forwarding, and interaction among layers can be made energy efficient. At the network level, energy aware topology and traffic management, better collaboration and communication among sensor nodes, and the reduced overhead can greatly help in the energy efficient objective of the WSN.

Optimized ML-MAC for Energy-Efficient Wireless Sensor Network Protocol:

In WSN, computation is distributed among a high number of nodes. Applications for these networks must use algorithms that are highly distributed, since only short-range communication is preferred in the context of the stringent power constraints. Also, since in applications in the areas of military and satellite communications, it is impossible to replace the nodes periodically, dense deployment of nodes is necessary to make network work for longer time. Thus making a densely deployed network energy-efficient requires implementation of a MAC protocol.

The various design constraints of WSNs include hardware constraints, power consumption, fault tolerance, sensor network topology, and transmission media. Optimization of parameters using ML-MAC protocol for Wireless Personal Area Networks (WPANs) [9], originally proposed in [10], is done by varying number of layers at different node densities. The simulations are done in QualNet version 6.1 network simulator for evaluation of the performance parameters like Network Lifetime, End-to-End Delay and Throughput. The performance parameters are calculated with MATLAB by using a second order empirical formula and a parameter estimator [11] is created. Fig. 2, 3 and 4 show the plots for Network Lifetime, Average End-to-End Delay and Average Throughput as observed from QualNet 6.1 simulator and as determined by estimator developed through MATLAB.

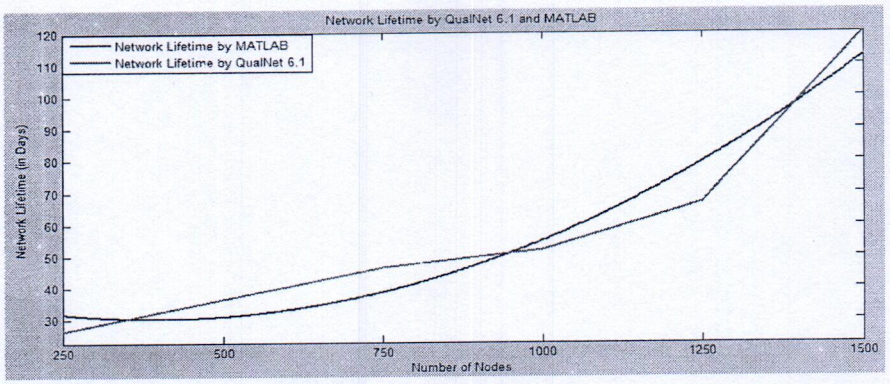

Fig 2: Network Lifetime

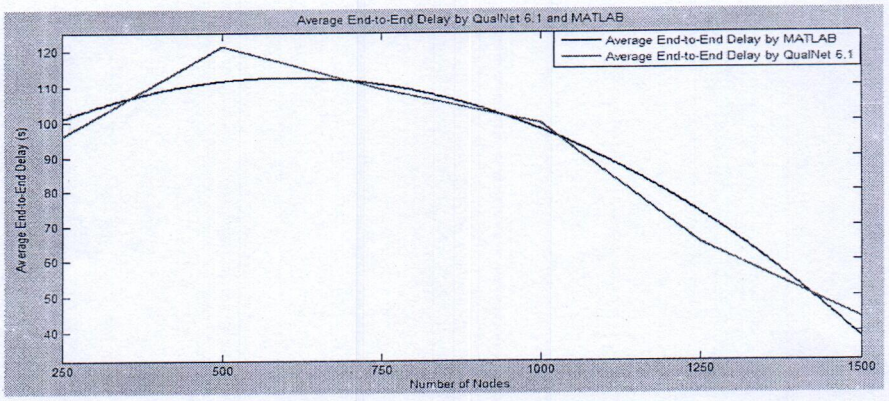

Fig 3: Average End-to-End Delay

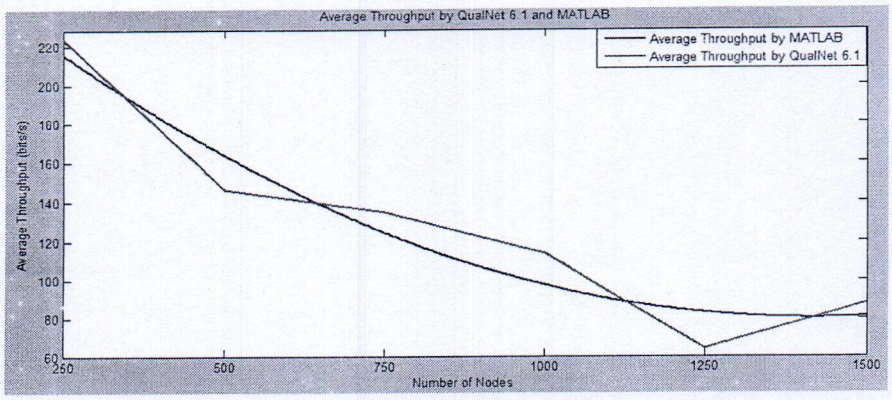

Fig 4: Average Throughput

Research Plan

Area: Energy-Efficient 3D Wireless Sensor Networks

Abstract:	One of the primary tasks of sensor networks is to monitor a *field of interest*(FoI). Sensors may monitor physical properties such as temperature, humidity,and air quality, or track the motion of objects moving within the FoI. Inmany cases sensor networks may initiate an automated reaction to the observedevents (actuation networks). As an example, motion detection sensorsmay trigger lights to turn on after motion has been detected, or sensors monitoringa patient's blood stream may automatically increase the intake of sugars inthe event of low-sugar-level detection. In actuation networks, in order to guaranteethe robustness of the decision mechanism, it is critical to improve theaccuracy and reduce the probability of false alarms. Recent interest in underwater acoustic ad hoc and sensor networks hints at the need to understand how to design networks in 3D.Although such ascenario may not be common at present, applications arebeing developed that will make three-dimensional networksincreasingly common in the near future.
Research Problem:	In reality,most wireless terrestrial networks are based on two-dimensional (2D) design; such networks operate in three dimensions (3D). Since most often the size (i.e., the length and the width) of such terrestrial networks is significantly larger than the differences in the third dimension (i.e., the height) of the nodes, the 2D assumption is somewhat justified and usually it does not lead to major inaccuracies. However, in some environments, this is not the case; the underwater, atmospheric, or space communications being such apparent examples.
Background:	Recently underwater acoustic ad hoc and sensor networks havegenerated a lot of interest among the researchers. Ocean column monitoring requires the nodes to beplaced at different depths of the water, thus creating a threedimensional network. Weather forecasting,

	climatemonitoring and fire detection in a multi-story building can also benefit if three-dimensional networks canbe deployed in the atmosphere. • SameeraPoduri et al. [14] proposed a set of local algorithms to construct efficient topologies in 3D that focuses on the problem of deployment and configuration of sensor networks in 3D, draws attention to the fundamental difficulties involved. • S. M. NazrulAlam et al. [12] considered the coverage and connectivity issues of 3D networks, where the goal is to find a node placement strategy with 100% sensing coverage of a 3D space, while minimizing the number of nodes required for surveillance. • Habib M. Ammari et al. [13] proposed an integrated concentric-sphere model to address coverage and connectivity in 3D WSNs in an integrated way. • Linghe Kong et al. [15] proposed a new coverage model called surface coverage. In surface coverage, the field of interest is a complex surface in 3D space and sensors can be deployed only on the surface. They showed that existing 2D plane coverage is merely a special case of surface coverage.
Research Design:	The design of 3D networks is surprisingly more difficult than the design of 2D networks.Coverage and connectivity are the important issues of three-dimensional networks, where all the node havethe same sensing range and the same transmission range, needs to beconsidered as primary design constraints for a 3D network. Issues [14] in extending existing designs for deployment and configuration to 3D: • to place the nodes in three-dimension such that the number of nodes required for surveillance of a 3D space is minimized, while guaranteeing 100% coverage • finding the minimum ratio of the transmission range and the sensing range of a 3D placement strategy

	• to choose the optimal deployment surface area, given a target region • to estimate the number of redundant sensors to be deployed to compensate for any possible sensor nodes failures The work that has been done in the field of 3D wireless sensor networks considered the problems and connectivity only. None of the works considered energy-efficiency as a challenging issue while designing a 3D network. I intend to continue my work in field of 3D networks while using a technique called ML-MAC [9,10] which provided very good results for energy-efficiency in case of a two-dimensional network.
Expected Results:	The proposed design is expected to perform better in terms of: • improved network lifetime by optimizing energy consumption • increased throughput (no. of data packets received per second) • improved duty cycle

Fig. 5 shows an example of 3D Wireless Sensor Network.

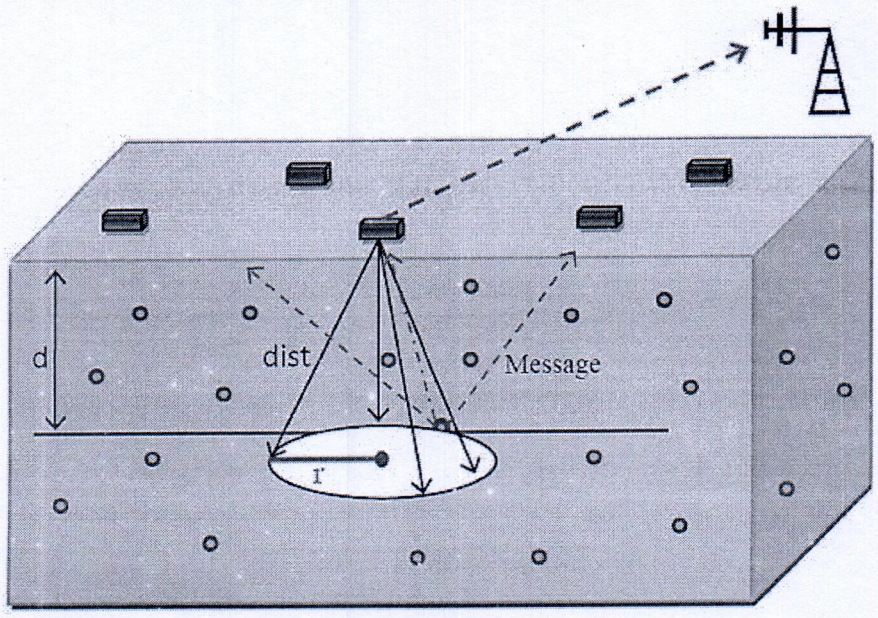

Fig 5: An example of 3D Wireless Sensor Network

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